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Result of the 60 tpd CO_2 capture pilot plant in European coal power plant with KS-1™ solvent

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Abstract

Mitsubishi Heavy Industries, Ltd. (MHI), in collaboration with Kansai Electric Power Co., Inc. (KEPCO), has developed and is continuing to improve upon an energy efficient chemical absorbent CO_2 recovery process called the KM CDR Process™ that utilizes the energy-saving CO_2 absorbent KS-1 ™ solvent. Long term, highly successful R&D activities since 1991, have led to the rapid commercial deployment of ten (10) CO_2 capture plants, with a maximum CO_2 capture capacity of 450 metric tons per day (tpd). One (1) further 500 tpd commercial plant in Qatar, currently under construction, will be commissioned in 2014. These plants have been delivered exclusively to the chemical industry; in the majority of the CO_2 recovery plants, CO_2 is stripped from natural gas fired steam reformer flue gas and used as a feedstock which reacts with ammonia to produce urea.

To ensure that the KM CDR Process™ and KS-1™ solvent could also be used in an environmental capacity for CCS application, the impacts of coal fired flue gas on the KM CDR™ process needed to be investigated. MHI constructed a 10 tpd demonstration plant at the Matsushima power station and operated it for more than 6,000 hours until concluding the successful test in 2008. The results and knowhow gained from the Matsushima test led to the construction and operation of the world's largest coal fired flue gas carbon capture plant in Alabama, USA. Southern Company 500 tpd plant began operation in June 2011 at Alabama Power's Plant Barry; the project became the world's first fully integrated black coal CCS project when SECARB began CO_2 injection in August, 2012.

MHI is continuing with numerous R&D activities related to amine CO_2 recovery at both Japan based R&D facilities and abroad. During 2012, MHI's overseas R&D focus has been Italy, at the 60 tpd pilot test plant located at Enel's Brindisi Power Station. The pilot plant test, utilizing KS-1™, was conducted over two (2) months capturing up to 60 tpd of CO_2 from European coal flue gas. This pilot plant is one of the biggest post combustion capture pilot plants in Europe; maximum flue gas flow of 12,000 Nm^3/h, CO_2 content range of 11 to 13 vol% with the flue gas pre-treated to remove SOx via wet electro filters. The pilot plant absorber column is 46m high and 1.5m in diameter, including 3 structured packing beds and a washing section.

The test program aim was to optimize operation using KS-1™, while monitoring and minimising amine emissions. Several parameters such as solvent concentration, regenerator pressure, packing height within the absorber and stripper were adjusted with a constant CO_2 capture rate to determine the optimum points. The MHI test results, utilizing KS-1™ were directly compared to the pilot plant operation benchmark, 30 wt% monoethanolamine (MEA). The results showed that when compared to the benchmark, KS-1™ required considerably less specific energy, had better tolerance to oxygen and significantly lower amine emissions.

Keywords: MHI; KEPCO; Enel; KM CDR Process™; KS-1™

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1.0 Introduction and Background

In response to climate change and the contribution of industrial CO_2 into the earth's atmosphere, MHI and KEPCO have been working together since 1990 to develop an advanced CO_2 capture chemical absorption process which can be applied to the power generation sector as an effective and economic means to reduce industrial CO_2 emissions. In 2010, Enel Italy, one of the biggest power suppliers, began to evaluate CO_2 capture performance of a commercially available amine, MEA, completing a Performance Verification Program. In 2012, after the MEA testing was concluded, Enel invited MHI to evaluate KS-1^{TM} at their test pilot plant located at Brindisi Power station.

2.0 CO_2 capture pilot plant - Brindisi Power Station, Italy

The Brindisi power station flue gas CO_2 content is approximately 13% at almost atmospheric pressure. Figure 1 shows the CO_2 capture pilot plant and location of the Brindisi power station; boiler unit 4 supplies a percentage of its flue gas stream to the plant. The corresponding specifications and process flow schematic are shown in Table 1 and Figure 2 respectively.

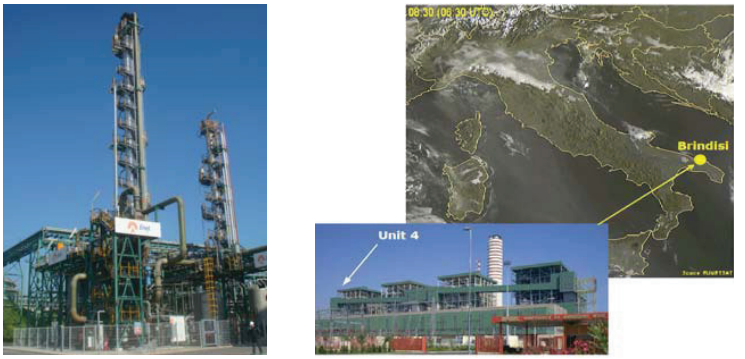

Figure 1. Enel's CO_2 capture Pilot Plant and location of Brindisi power station

Table 1. CO_2 Capture Pilot Plant Specifications

Description	Unit
Flue Gas Flow Rate	12,000 [Nm^3/h]
CO_2 Recovery Volume	60 [tpd]
System Configuration	DeSOx-Wet ESP-Absorber-Regenerator
Absorber Size	46[m] height ,1.5[m]dia

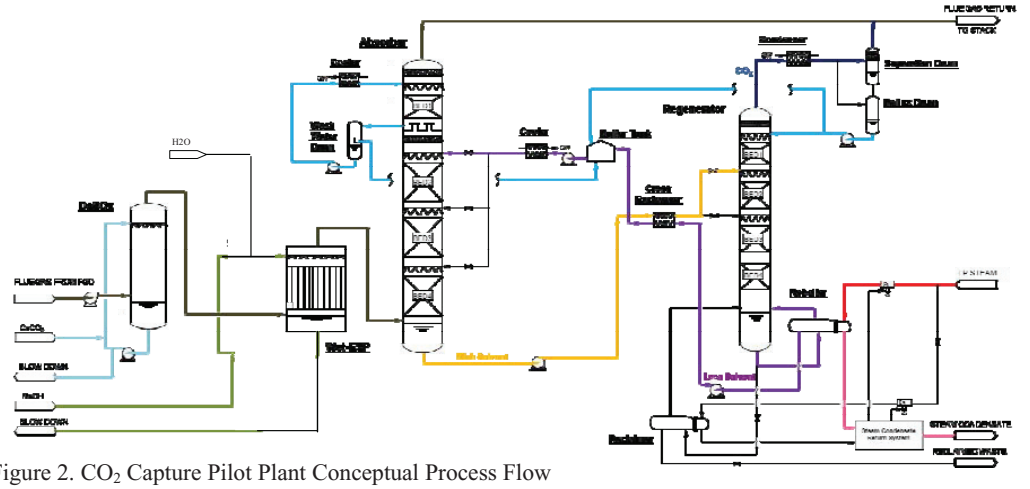

Figure 2. CO_2 Capture Pilot Plant Conceptual Process Flow

3.0 Coal fired flue gas Performance Verification Test Program

The performance verification test was conducted between January and March, 2012. During the test MHI's proprietary KS-1™ solvent was evaluated in Enel's 60tpd CO_2 capture pilot plant with European coal flue gas. Solvent circulation rate, operating pressure, absorber packing height and solvent concentration were evaluated separately to assess the impact of each parameter on CO_2 capture performance. The Performance Verification Test program schedule that was undertaken is shown in Table 2 below.

MONTH	Jan.				Feb.					Mar.			
WEEKS	1	2	3	4	5	6	7	8	9	10	11	12	13
Adjustment operation				↔									
Optimization of solvent circulation flow rate						↔							
Change of pressure in Stripper						↔							
Change of CO_2 efficiency										↔			
Change of Packing height at Absorber / Stripper								↔		↔			
Change of KS-1™ concentration											↔	↔	

Table 2. Performance Verification Test Program Schedule.

4.0 Test Result

4.1 Performance evaluation result and comparison with other typical amine.

In this parametric test, changes to both lean solvent flow rate and absorbing section packing height were studied in isolation to evaluate the lowest heat consumption for each condition. It was found that KS-1™ can achieve a lower heat consumption, MEA: app 1.5[kg-steam/kg-CO_2]>> KS-1™: app 1.2 [kg-steam/kg-CO_2], with a lean solvent flow rate approximately 25% lower than MEA 30wt% as shown in Figure 3.

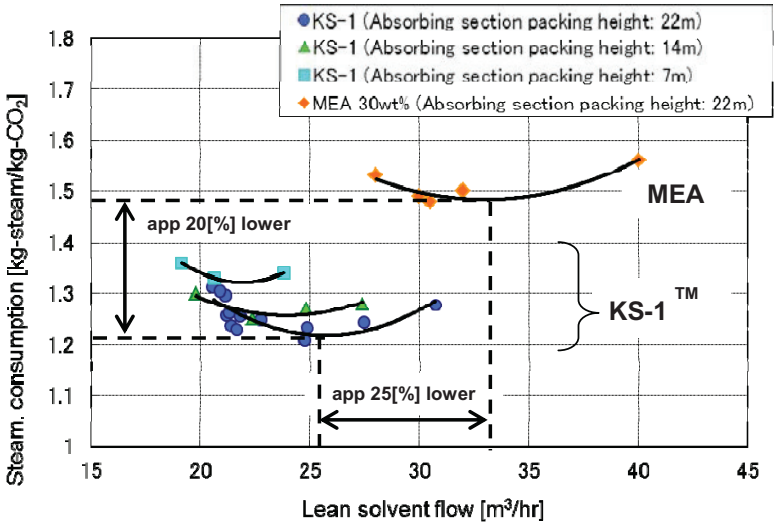

Figure 3. Parameterized performance test result.

4.2 Amine degradation evaluation result.

Theoretically, oxygen contained in the flue gas has a tendency to degrade amine solvent and produce ammonium (NH_3). The KS-1™ amine emission campaign result, Table 3, verified that the NH_3 concentration in the treated flue gas was lower than that of MEA. Therefore, it can be concluded that KS-1™ has greater tolerance to oxygen.

Solvent		MEA(30[wt%])		KS-1™			
Date		25th Jan 2011		30th Jan 2012	31st Jan 2012	9th Feb 2012	15th Feb 2012
NH_3	[mg/Nm^3]	14	14	1.5	0.5	0.2	0.3

Table 3. Amine emission campaign result (NH_3 concentration in the treated flue gas)

5. Summary

The performance of MHI's proprietary amine KS-1™ solvent, developed by MHI and KEPCO, was compared with MEA and evaluated in the 60tpd test pilot plant at Enel's coal Brindisi Power station, Italy. In this test program, it has been proven that under the same conditions KS-1™ solvent achieved lower heat consumption and lower solvent circulation flow rate than typical MEA (30wt%). It was also proven that KS-1™ has better oxygen tolerance than MEA.

MHI are continuing to further reduce the energy penalty and environmental impact of CO_2 recovery plants by continuing to improve the process, thus helping to facilitate the future wide scale deployment of CO_2 capture technology as an effective counter measure against climate change.

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